3 Sets of 3-5 Slides

1.) Guest Observer Program
- motivation, engagement, and scale
- HUDF vs WFIRST deep field example
- example Milky Way galaxy science (star formation, astrometry w/ GAIA)
- example extragalactic slide (galaxy evolution and lensing)

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- Complementary, but more powerful than Euclid
- Panchromatic imaging w/ LSST
- SDSS + Keck → WFIRST + ELTs

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25% of AFTA is a Guest Observer Program

Peer-Review and Competed Guest Observer Program

Establishes broad community engagement
Tackles diverse set of astrophysical questions in changing paradigms
Maximizes synergies with JWST, Euclid, LSST, and other future telescopes
Open competition inspires creativity
Ensures long-term scientific discovery potential

Massive Outpouring of Interest

50+ potential GO science programs in SDT report
Planetary, stellar, galactic, and extragalactic astronomy

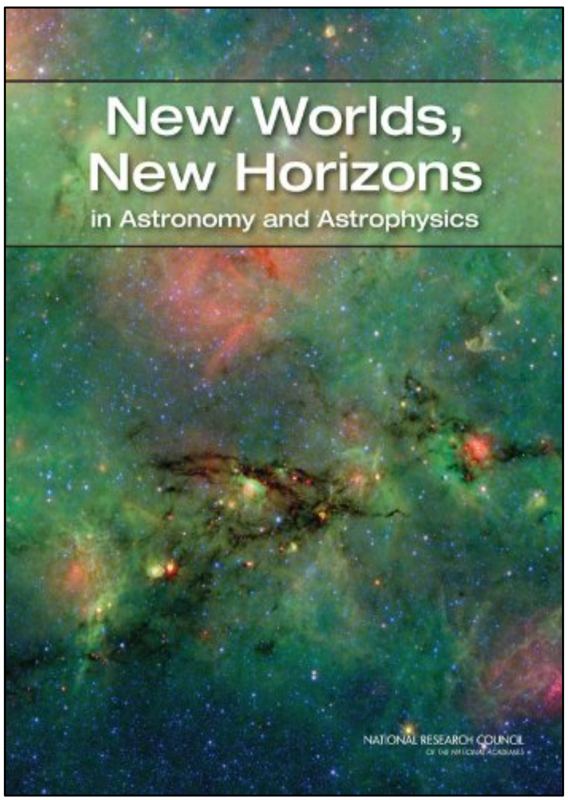
AFTA's Guest Observer Program Addresses NWNH

Frequently discussed

#1 Large-Scale Priority - Dark Energy, Exoplanets

#1 Medium-Scale Priority - New Worlds Tech. Development
(prepare for 2020's planet imaging mission)

But, AFTA provides improvement over IDRM in many other areas….



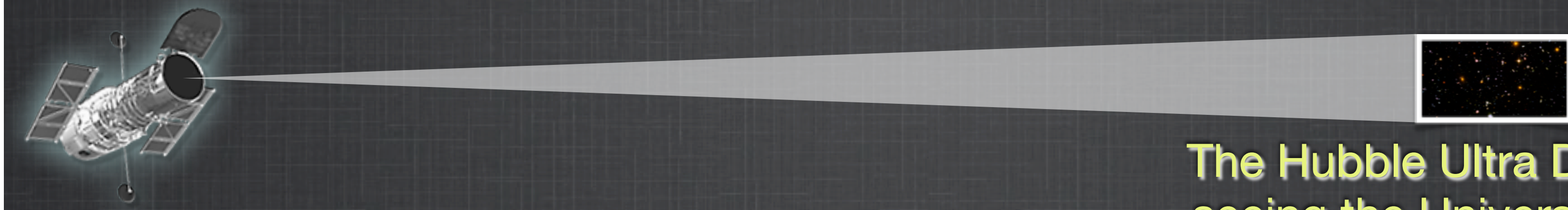
5 Discovery Science Areas

ID & Characterize Nearby Habitable Exoplanets ✔
Time-Domain Astronomy ✔
Astrometry ✔
Epoch of Reionization ✔
Gravitational Wave Astrometry

20 Key Science Questions

Origins **(7/7 key areas)**
Understanding the Cosmic Order **(6/10 key areas)**
Frontiers of Knowledge **(3/4 key areas)**

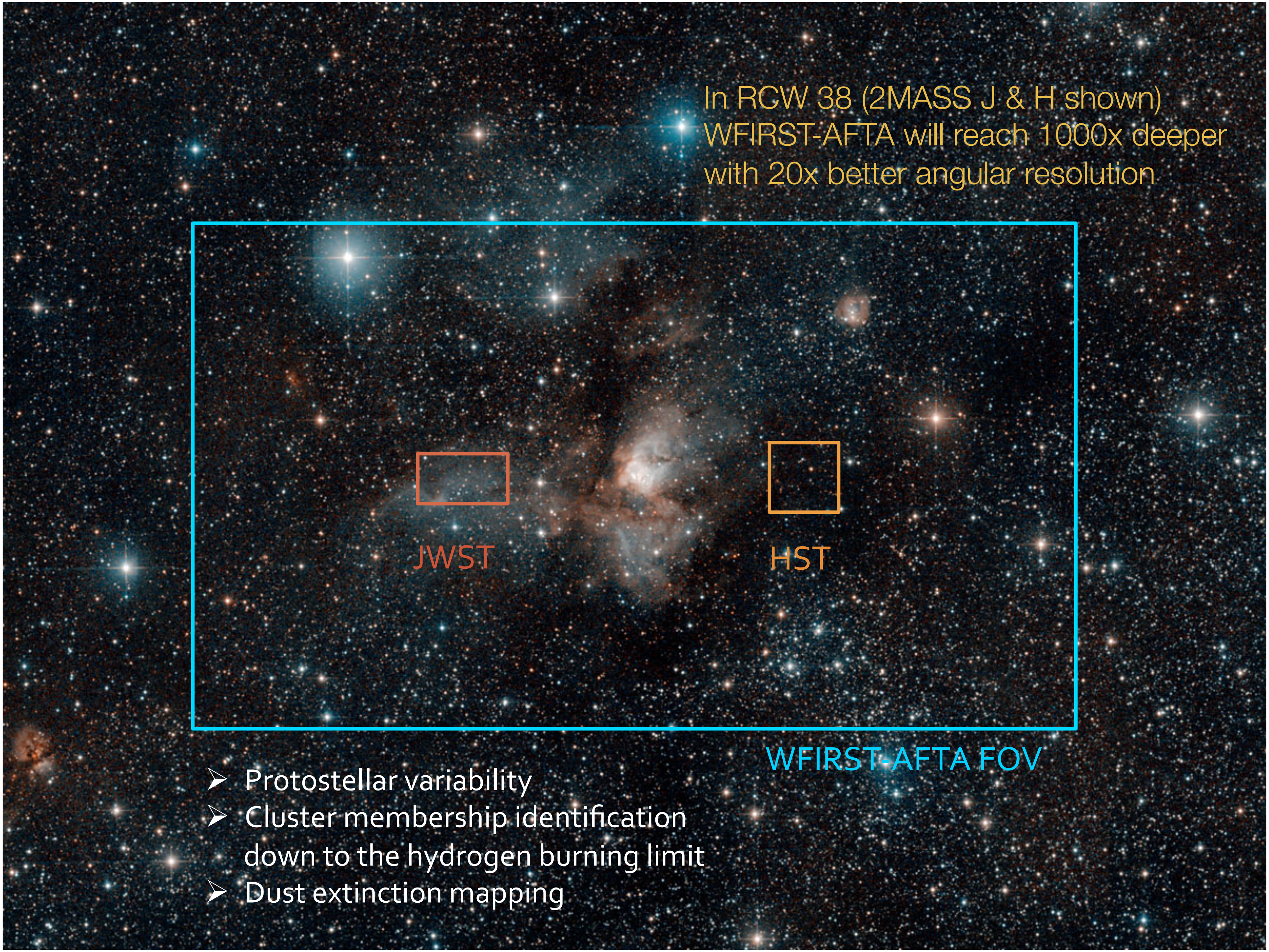
Hubble - A Spectacular Start



The Hubble Ultra Deep Field
seeing the Universe, 10,000
galaxies at a time

AFTA/WFIRST - Hubble X 100

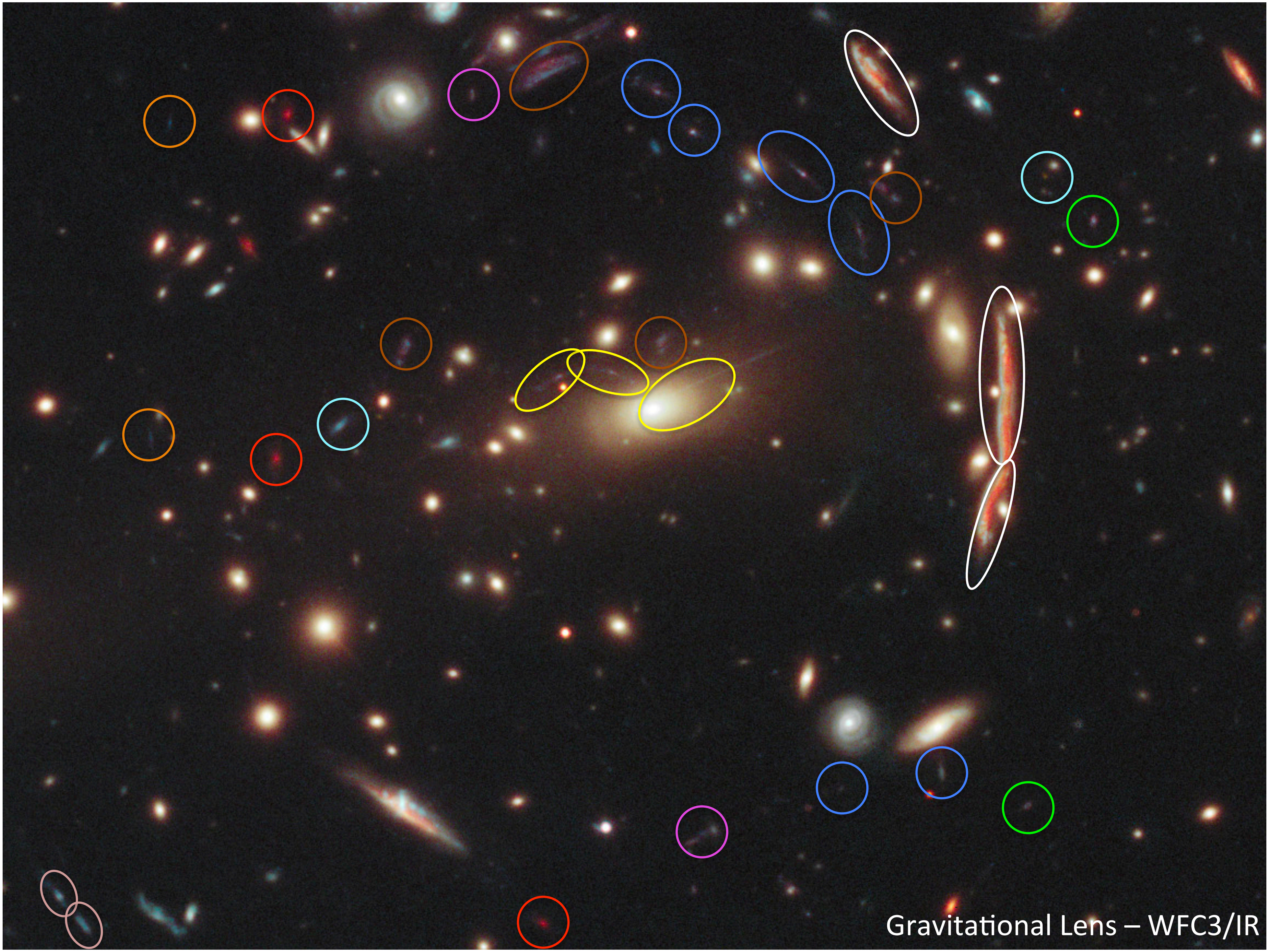
An AFTA/WFIRST Deep Field
A New Window on the Universe - **1,000,000** galaxies at a time

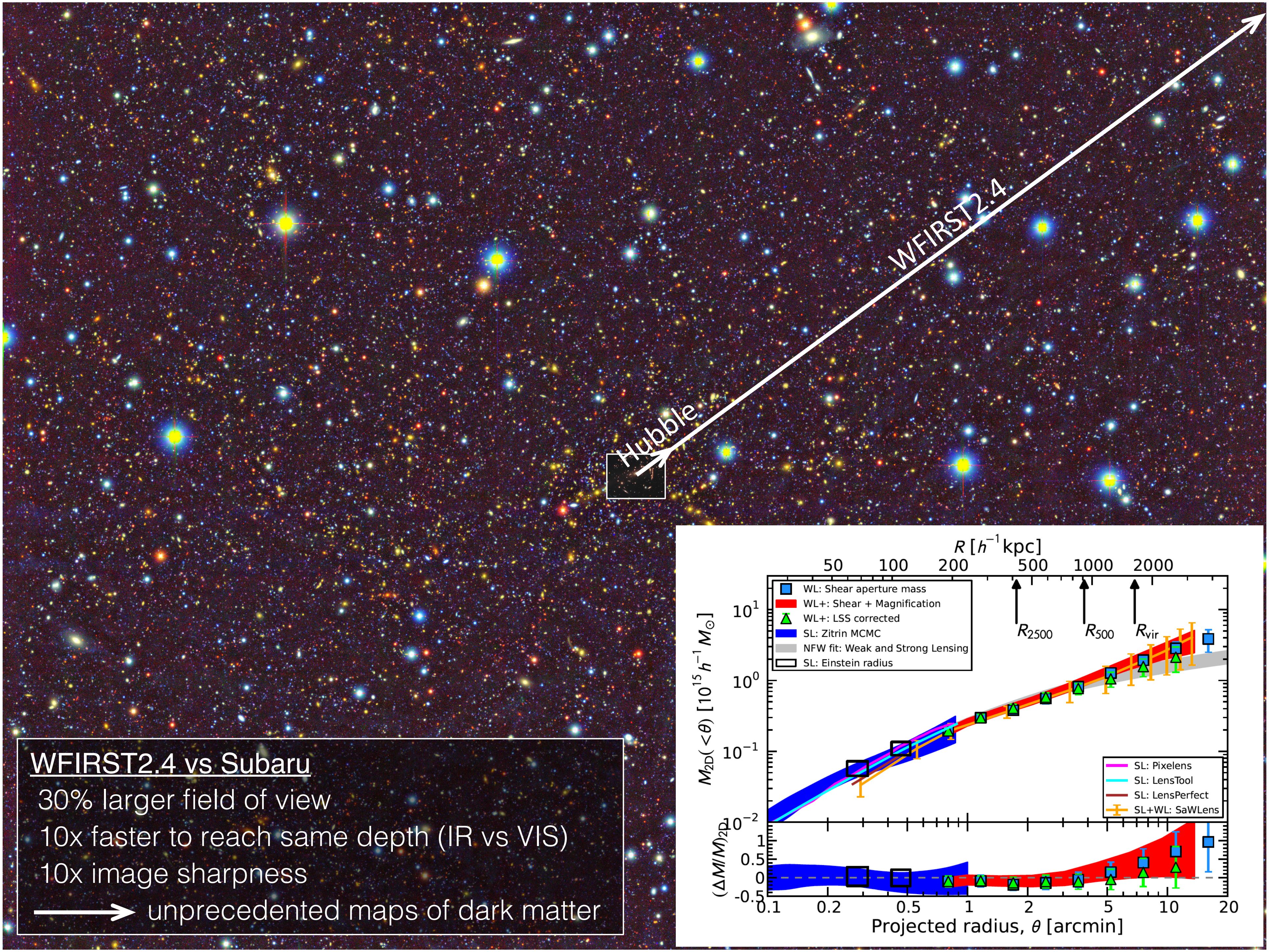


In RCW 38 (2MASS J & H shown)
WFIRST-AFTA will reach 1000x deeper
with 20x better angular resolution
JWST
HST
WFIRST-AFTA FOV
➢ Protostellar variability
➢ Cluster membership identification down to the hydrogen burning limit
➢ Dust extinction mapping

Extragalactic Slide

Lensing


Gravitational Lens – WFC3/IR



WFIRST2.4
Hubble
WFIRST2.4 vs Subaru
30% larger field of view
10x faster to reach same depth (IR vs VIS)
10x image sharpness
unprecedented maps of dark matter
R [h^-1 kpc]
50 100 200 500 1000 2000
WL: Shear aperture mass
WL+: Shear + Magnification
WL+: LSS corrected
SL: Zitrin MCMC
NFW fit: Weak and Strong Lensing
SL: Einstein radius
R2500
R500
Rvir
M2D(<θ) [10^15 h^-1 M⊙]
SL: Pixelens
SL: LensTool
SL: LensPerfect
SL+WL: SaWLens
(ΔM/M)2D
Projected radius, θ [arcmin]

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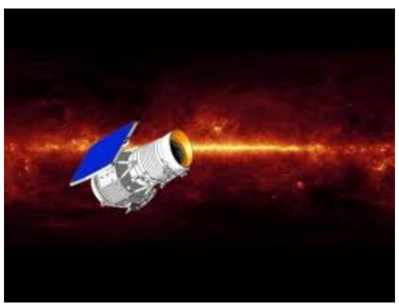
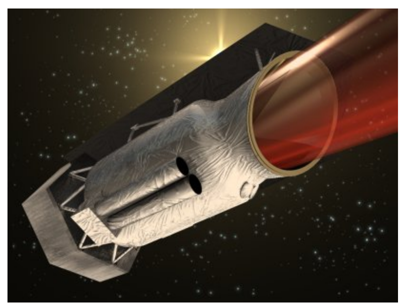
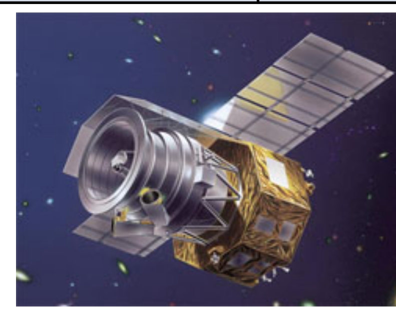
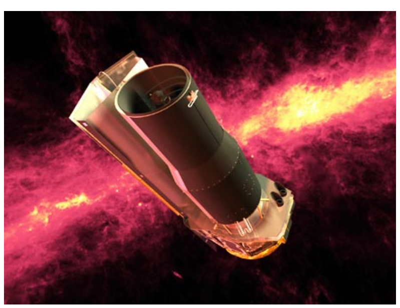
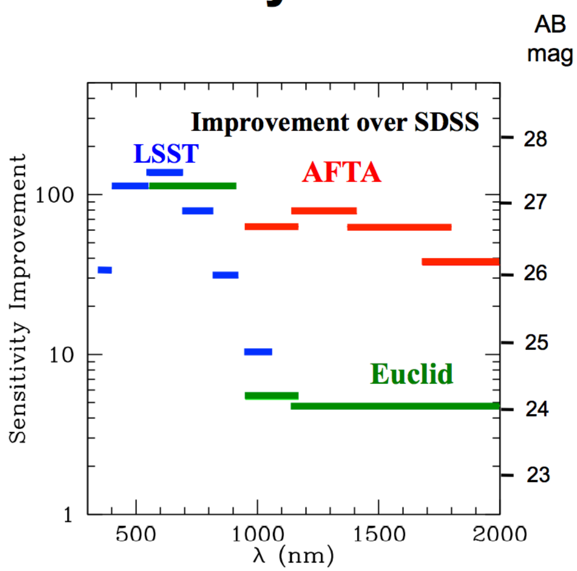
Near-IR space based capabilities

instrument	telescope	pixel scale	field of view	wavelength
WISE	0.4m	2.75 arcsec	47 arcmin	3 – 28 μm
ISO	0.6m	12 arcsec	3 arcmin	2.4 – 240 μm
Akari	0.7m	1.5 arcsec	10 arcmin	1.8 – 180 μm
Spitzer	0.85m	1.2 arcsec	5.2 arcmin	3 – 8 μm
Hubble/NICMOS	2.4m	0.04 – 0.20 arcsec	0.2 – 0.9 arcmin	0.8 – 2.5μm
Hubble/WFC3 IR	2.4m	0.13 arcsec	2 arcmin	0.9 – 1.7 μm
AFTA/WFIRST	**2.4m**	**0.11 arcsec**	**0.3 degree**	**1.0 – 2.0 μm**

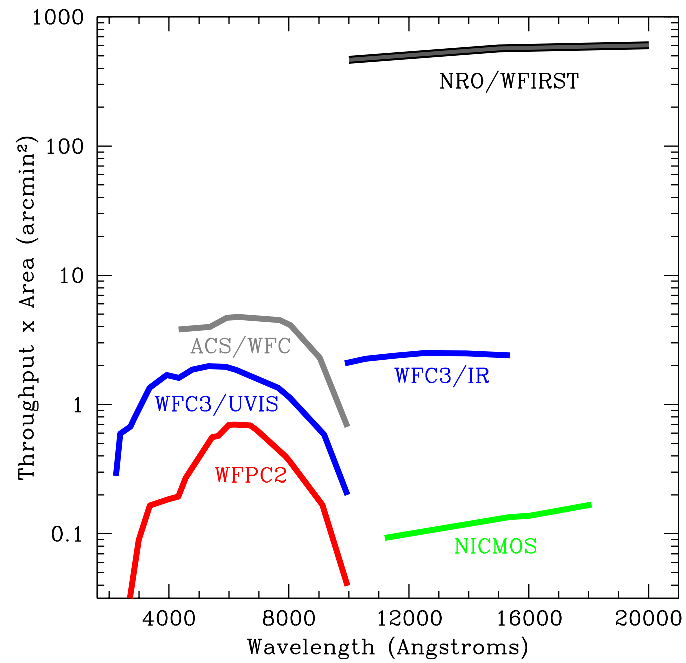
WFIRST-AFTA Surveys

- Multiple surveys:
  - High Latitude Survey
    - Imaging, spectroscopy, supernova monitoring
  - Repeated Observations of Bulge Fields for microlensing
  - 25% Guest Observer Program
  - Coronagraph Observations
- Flexibility to choose optimal approach



High Latitude Survey is 2.5x fainter and 1.6x sharper than IDRM

7



Milky Way: Luminous and Dark Matter

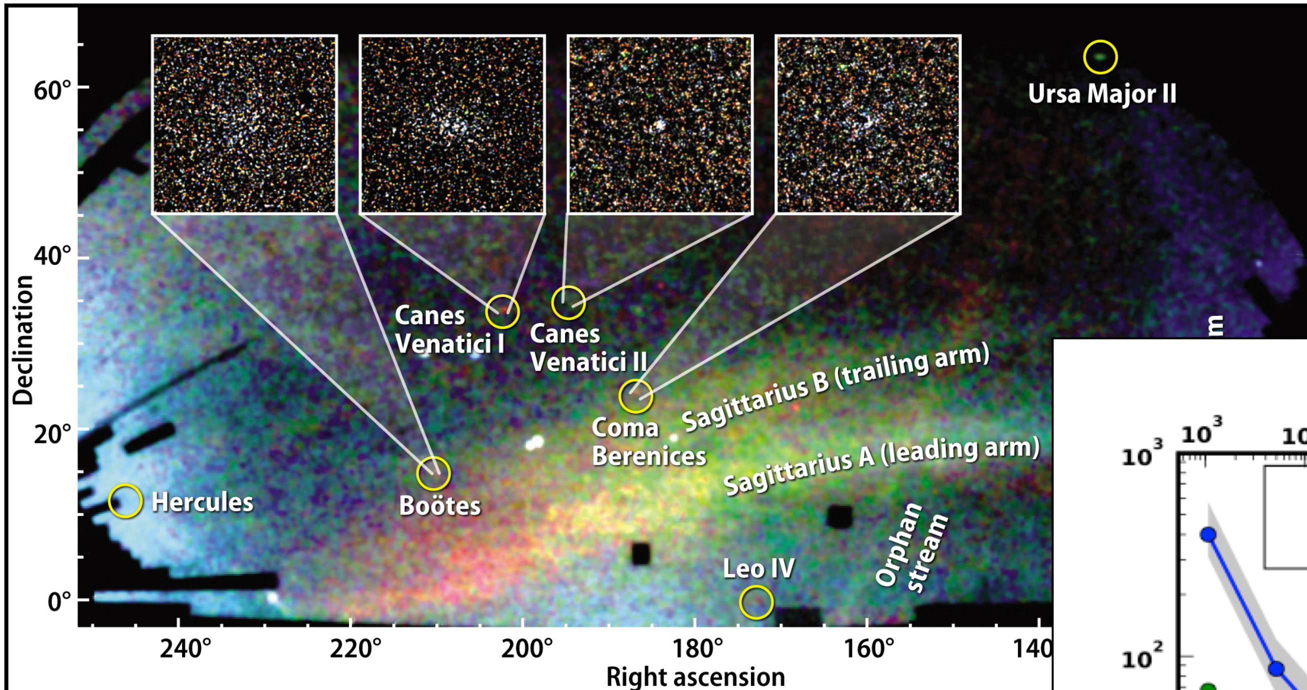
Masses of the Faintest Milky Way Satellites
80 micro-arcsec/year gives individual star internal velocities.
→ provides estimates of dark matter mass and density
→ <2 km/s for 50 stars @ 100 kpc, in 3 years

The Mass of the Milky Way
Tangential velocities of distant tracers in the Milky Way halo
→ <40 km/s error in v_{TAN} at 100 kpc, less than the expected velocity dispersion
→ Breaks the mass-anisotropy degeneracy in the distant halo

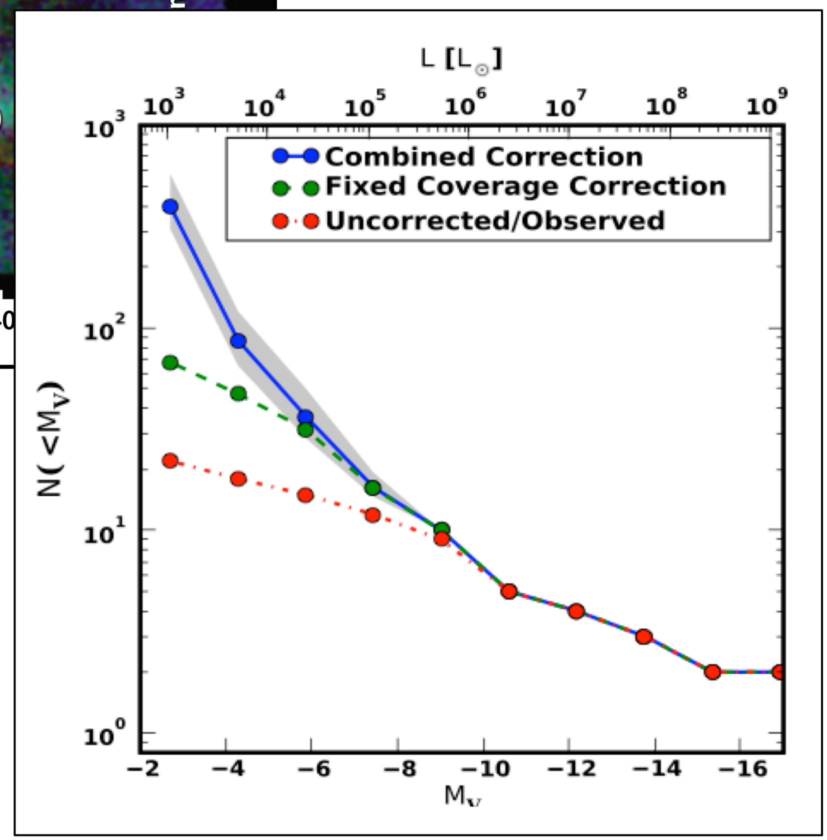
Cold vs Warm Dark Matter
Distinguish central density profiles
Extrapolate dark matter mass profiles
Current v_{RAD} lead to degeneracy b/w the central slope of DM profile and vel anisotropy.

Dark Matter Properties through Luminous Tracers

<u>AFTA will survey 2000 sq deg of MW Halo at Hubble's power and IR image quality</u>

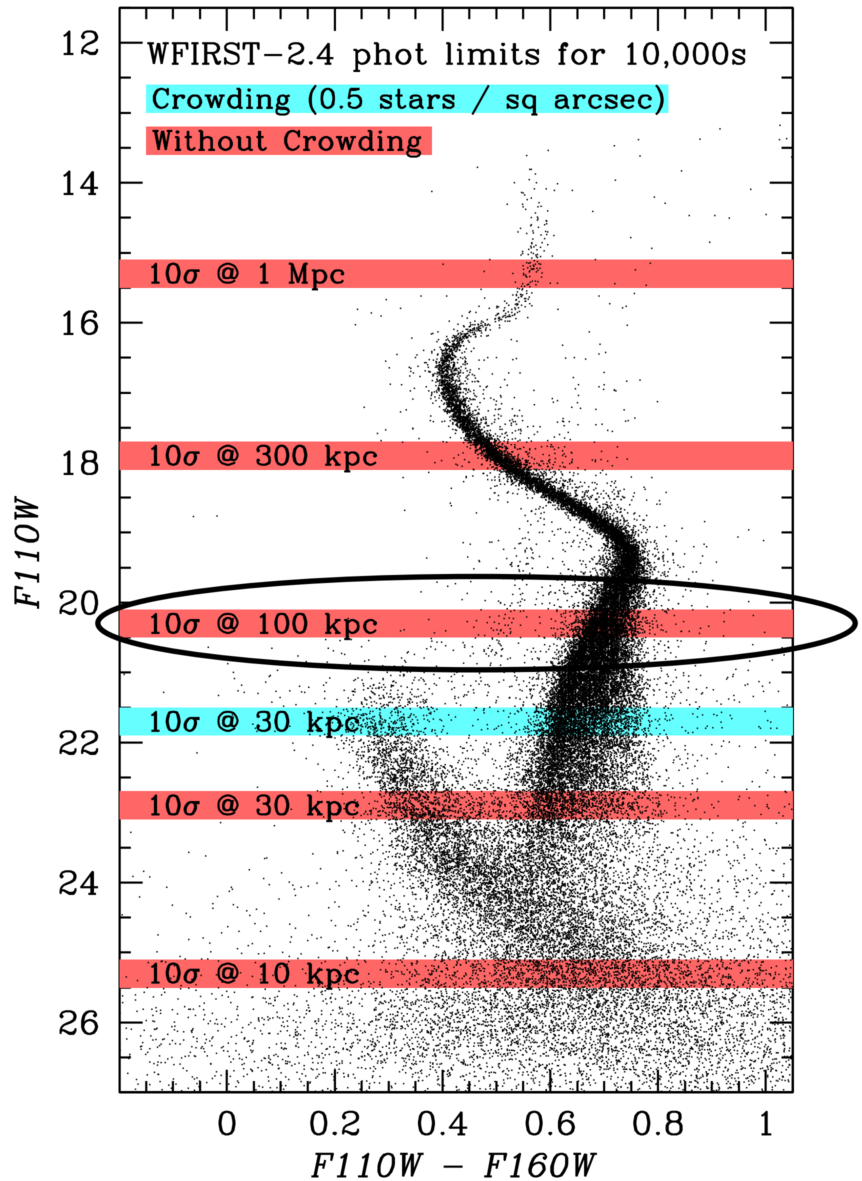


Current census of Milky Way DM-dominated streams and dSphs is heavily incomplete



Discovery: Luminous and Dark Matter

A stellar population in the IR (Kalirai et al. 2012)



<u>M dwarfs out to the edge of the Milky Way</u>

- Exquisite star/galaxy separation
- High-precision photometry
- Takes advantage of rising stellar lum func.

→ Discovery of dozens of low SB systems

→ IMFs, SFHs, SB profiles, and structure

Extragalactic Slide

High z LF

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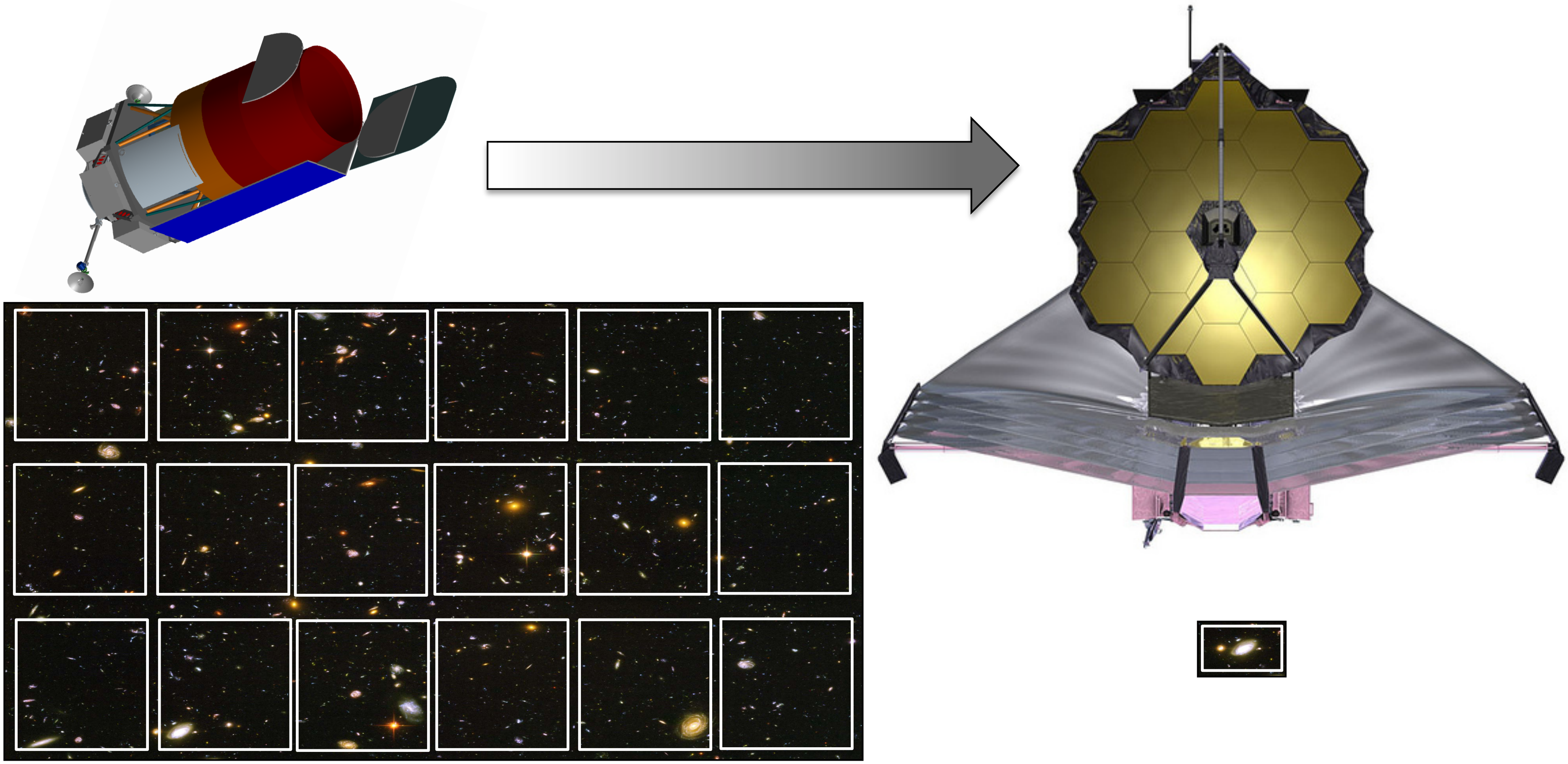
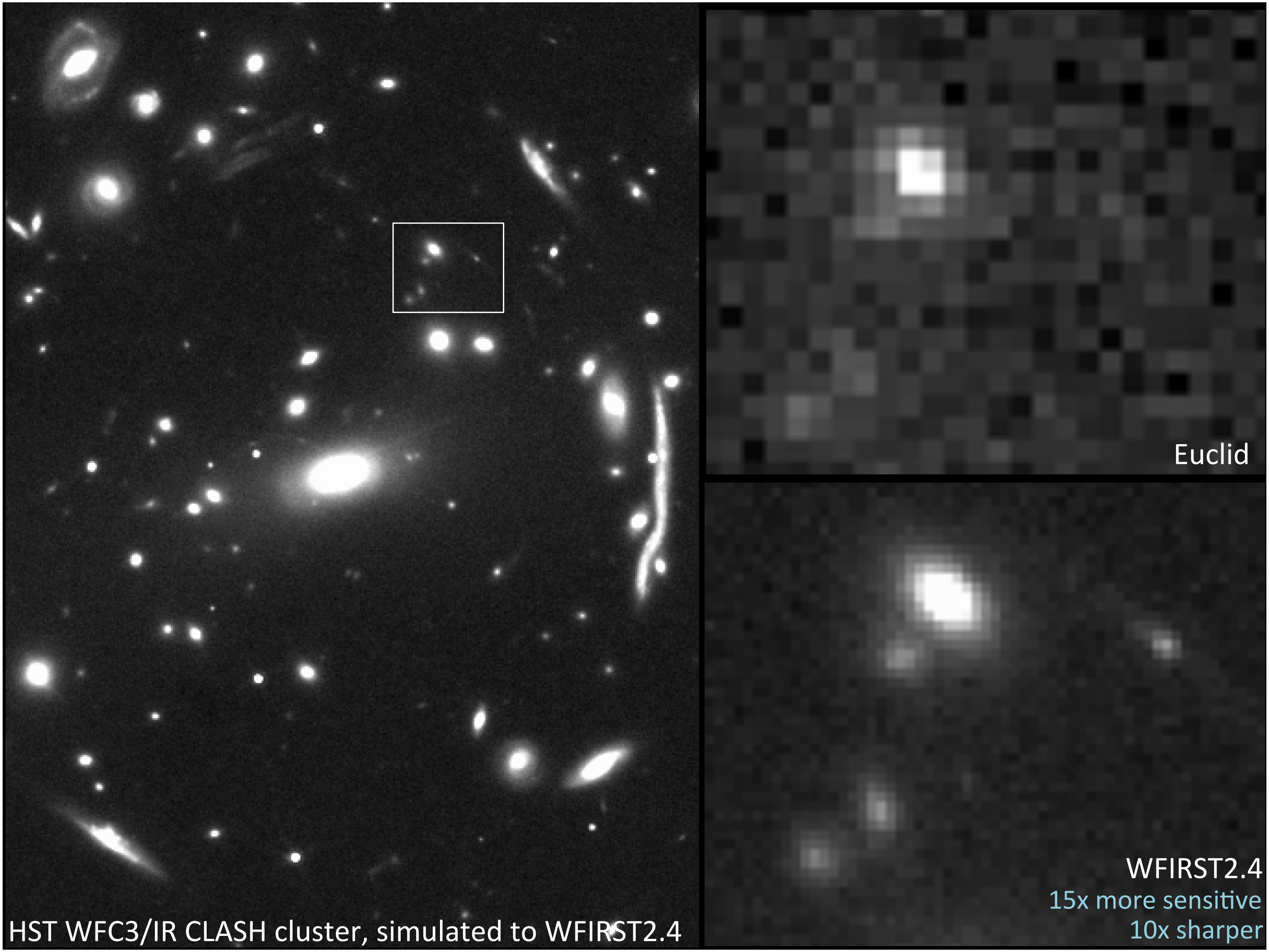
WFIRST2.4 Enhances JWST Science

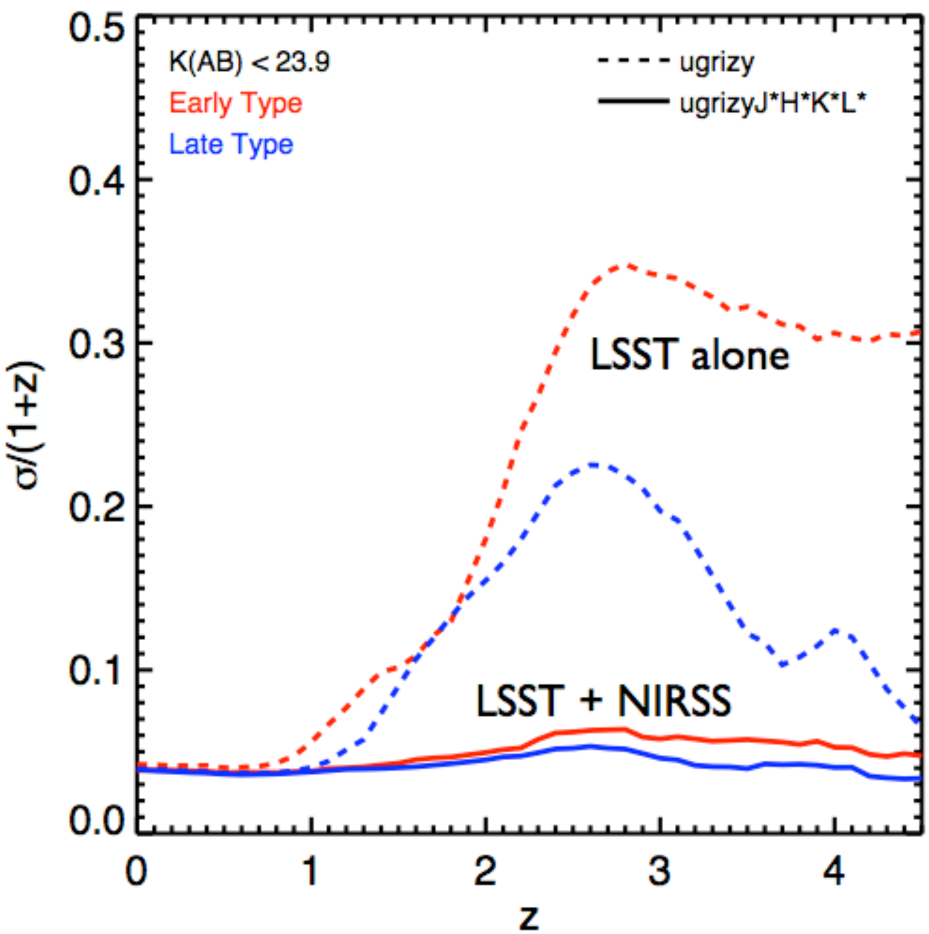


- WFIRST2.4 discovery of high-z galaxies ⟶ JWST NIR and MIR detailed spectroscopy
- WFIRST2.4 finds first stellar explosions ⟶ JWST light curves and host galaxy properties
- WFIRST2.4 wide field survey of galaxies ⟶ JWST SNe spectra with pre-detonation images
- WFIRST2.4 maps of halo tidal streams ⟶ JWST ages, abundances of substructure
- WFIRST2.4 monitoring of exoplanets ⟶ JWST transit spectroscopy of atmospheres

Appendix B of SDT Report


Euclid
WFIRST2.4
15x more sensitive
10x sharper
HST WFC3/IR CLASH cluster, simulated to WFIRST2.4

stellar and dark matter content of galaxies to z~3

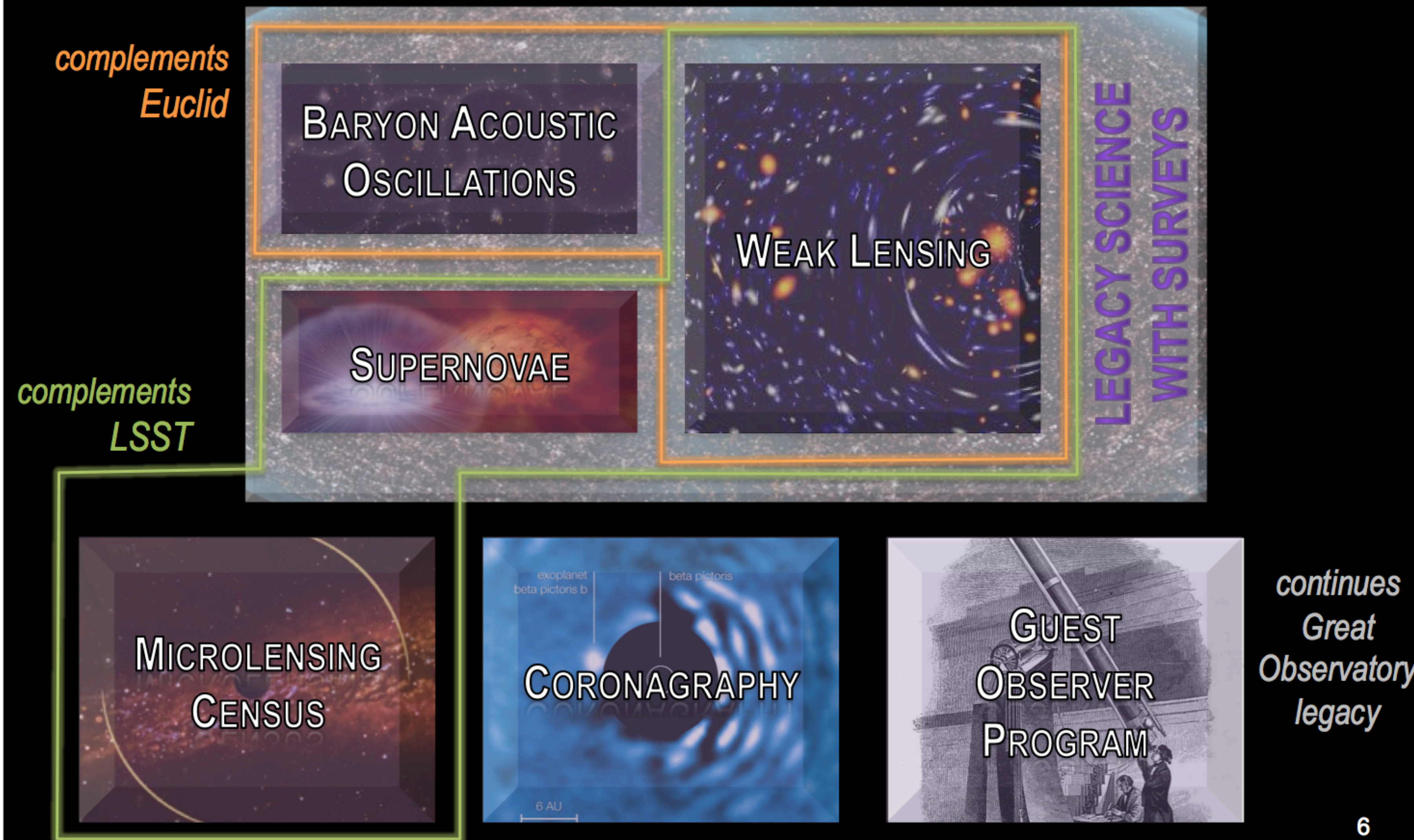


simulated photometric redshift accuracy, assuming 4% floor

WFIRST will map the build-up of galaxies

- significantly improved photometric redshifts; essential for both weak lensing and galaxy evolution science
- based on UDF, 80% of galaxies will be resolved by WFIRST DRM to *H*~25; much better for WFIRST NEW
- WFIRST will do for 1<z<3 universe what SDSS did for z<0.2 universe
- improved selection of samples based on stellar mass, not star formation rate
- measure the cosmic merger rate of galaxies with vastly improved statistics, particularly at z>1

WFIRST Science



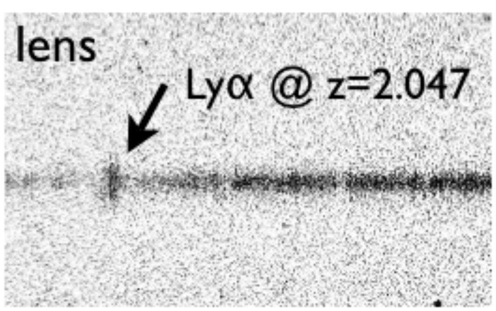
Extra Slides

[thanks especially to Phil Marshall, Leonidas Moustakas & Jean-Paul Kneib]

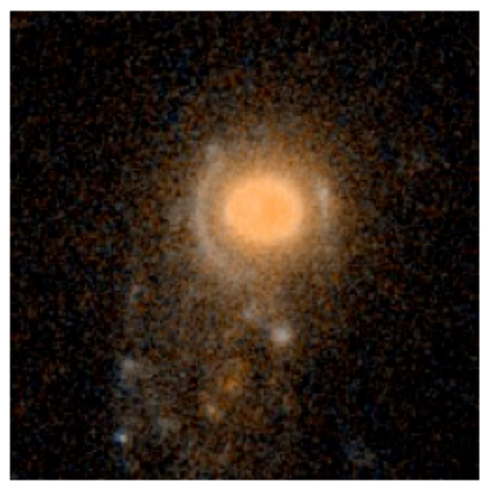
strong lensing

WFIRST will find many new strong gravitational lenses

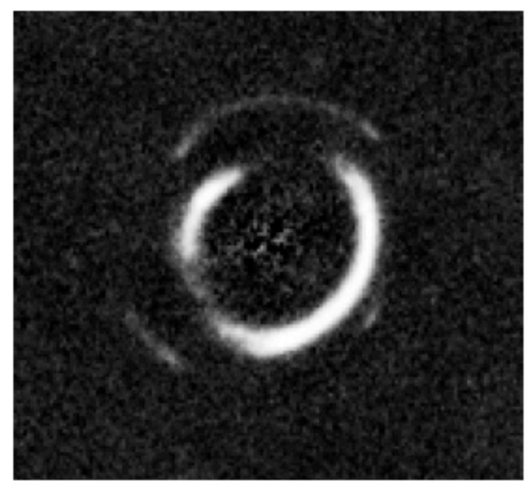
- informs about the mass and mass distribution of the lensing source
- affords us a magnified view of the background lensed source
- SNAP predictions were ~100x increase in number of galaxy-galaxy lenses
- cosmological constraints from lens statistics ("lens redshift test")
- rare "compound lenses" particularly interesting cosmologically
- lensed supernovae also cosmologically exciting
- lensed time-variable sources useful for studying dark matter substructure
- combining strong and weak lensing analyses for groups/clusters probes dark matter
- likely best done at optical wavelengths, but deep near-IR still very interesting



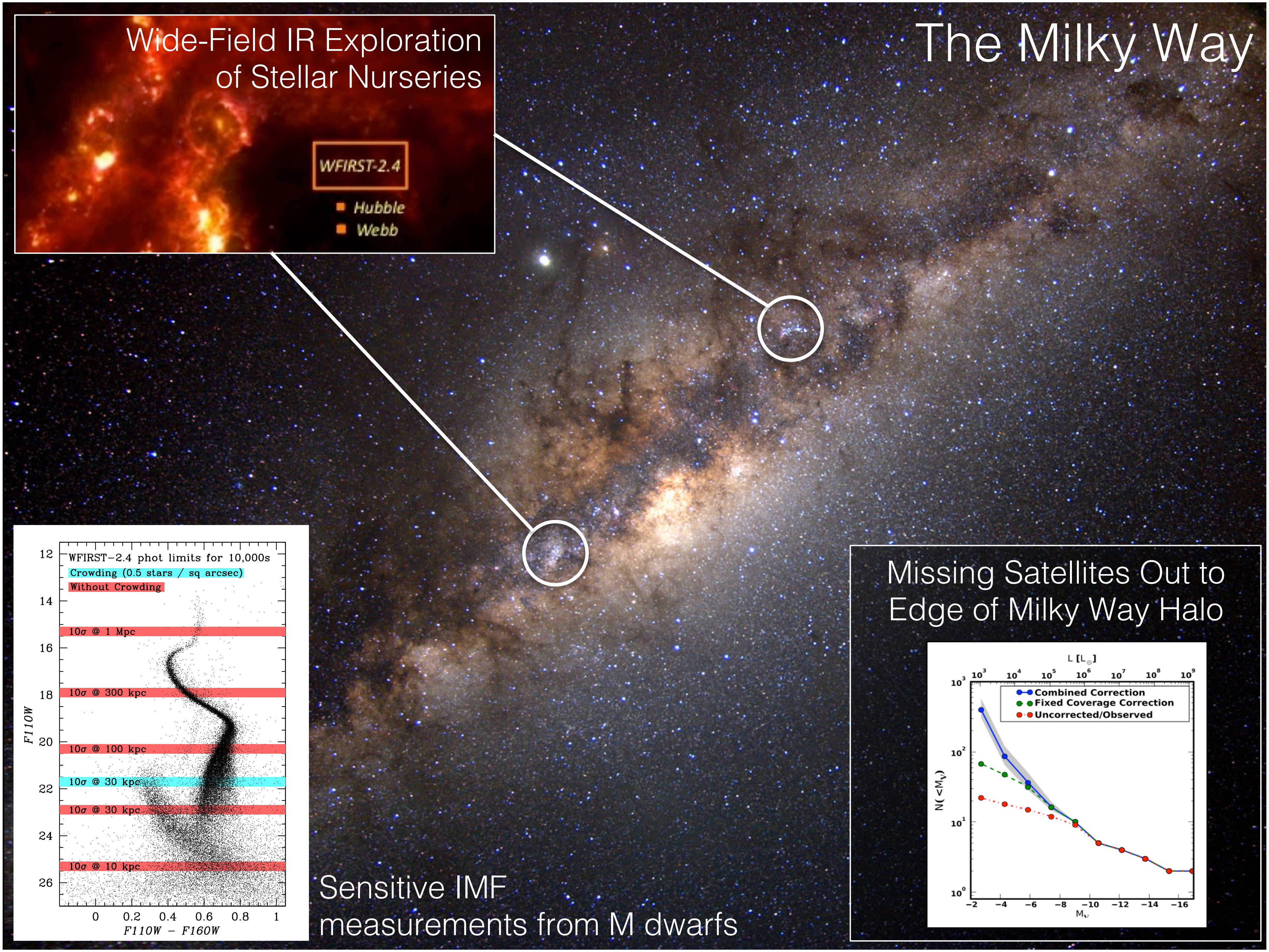
slitless spectra lens



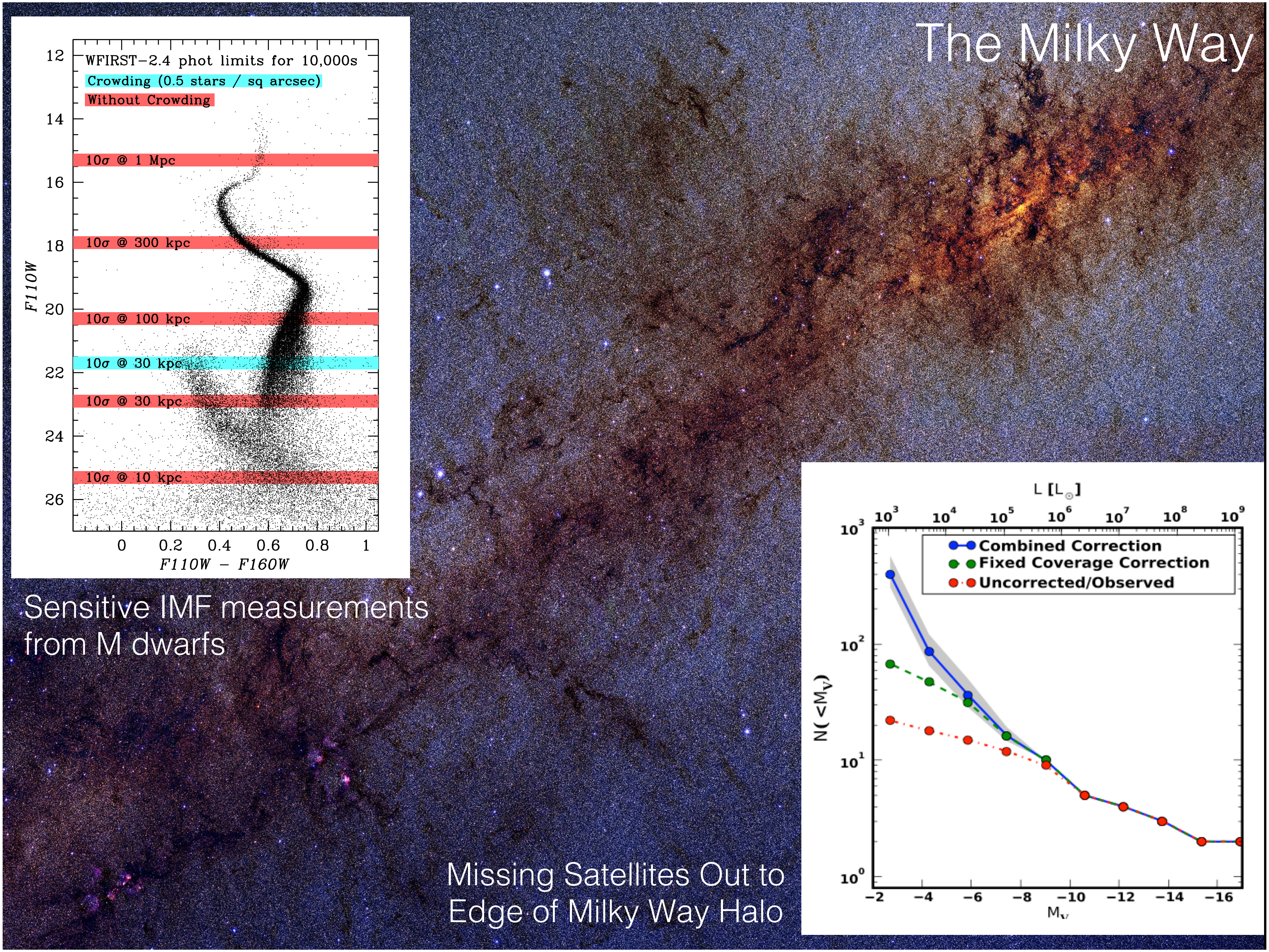
SLACS lens



compound lens



The Milky Way
Wide-Field IR Exploration of Stellar Nurseries
WFIRST-2.4
Hubble
Webb
WFIRST−2.4 phot limits for 10,000s
Crowding (0.5 stars / sq arcsec)
Without Crowding
10σ @ 1 Mpc
10σ @ 300 kpc
10σ @ 100 kpc
10σ @ 30 kpc
10σ @ 30 kpc
10σ @ 10 kpc
F110W
F110W − F160W
Sensitive IMF measurements from M dwarfs
Missing Satellites Out to Edge of Milky Way Halo
Combined Correction
Fixed Coverage Correction
Uncorrected/Observed



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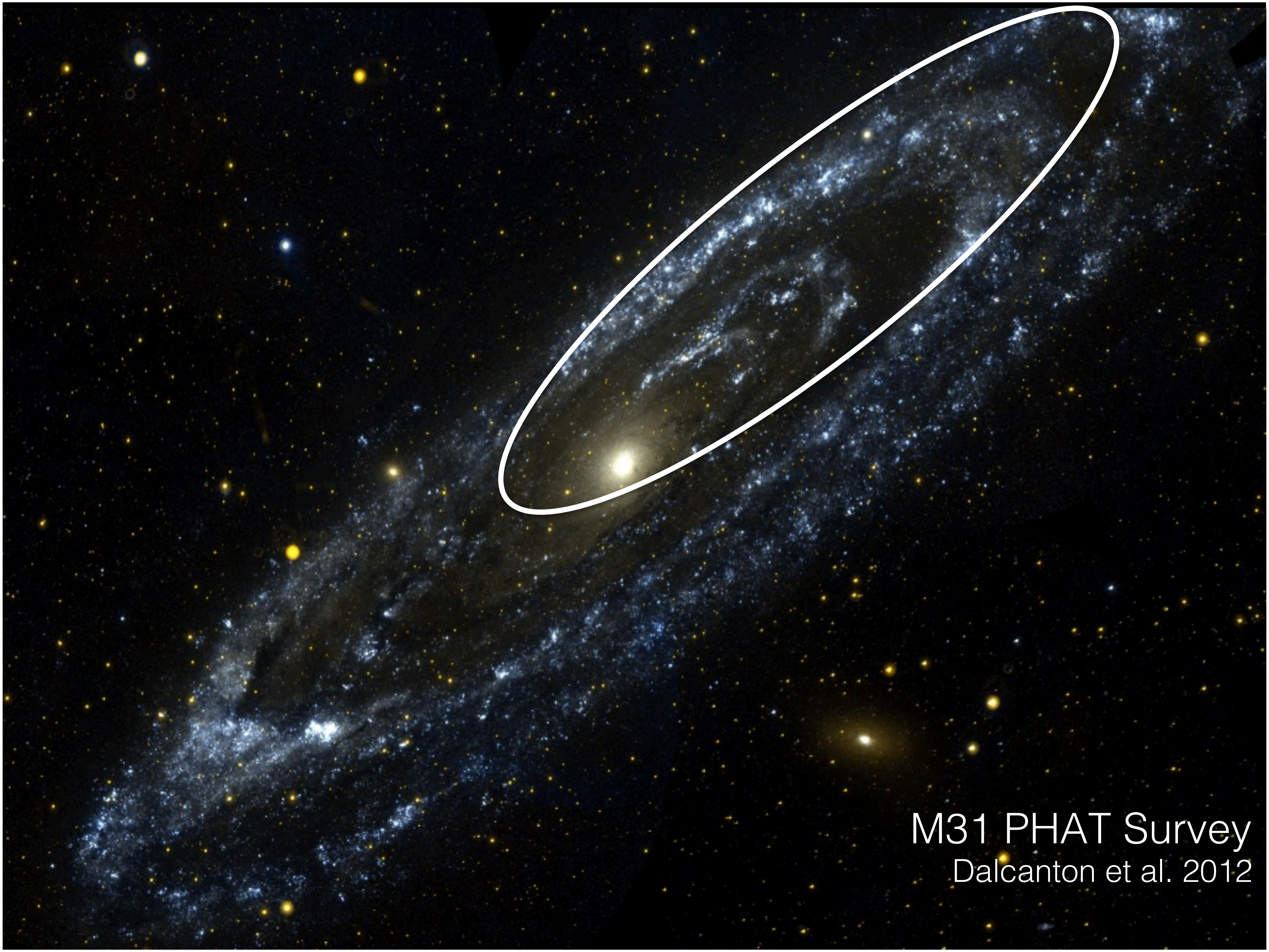
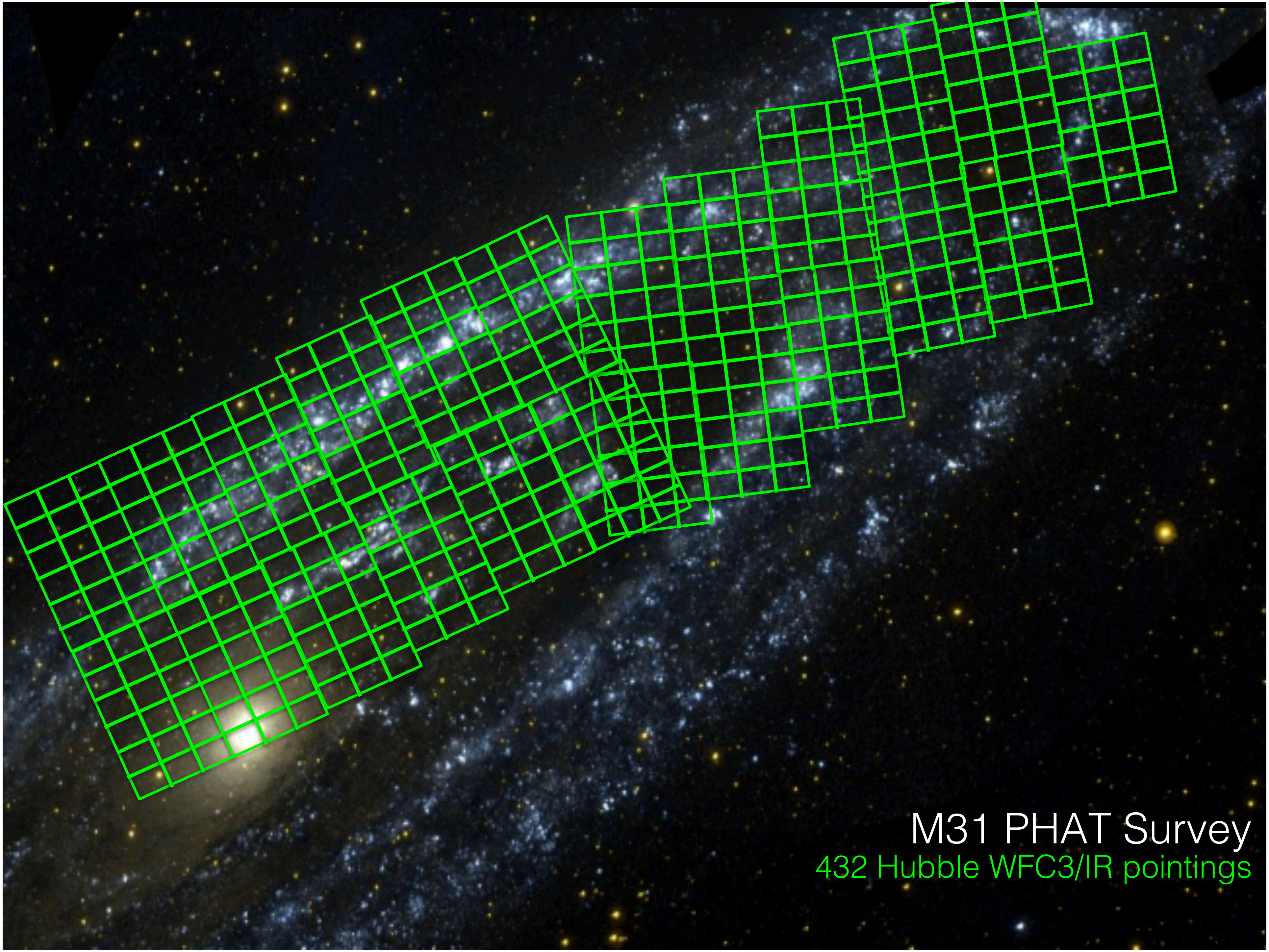
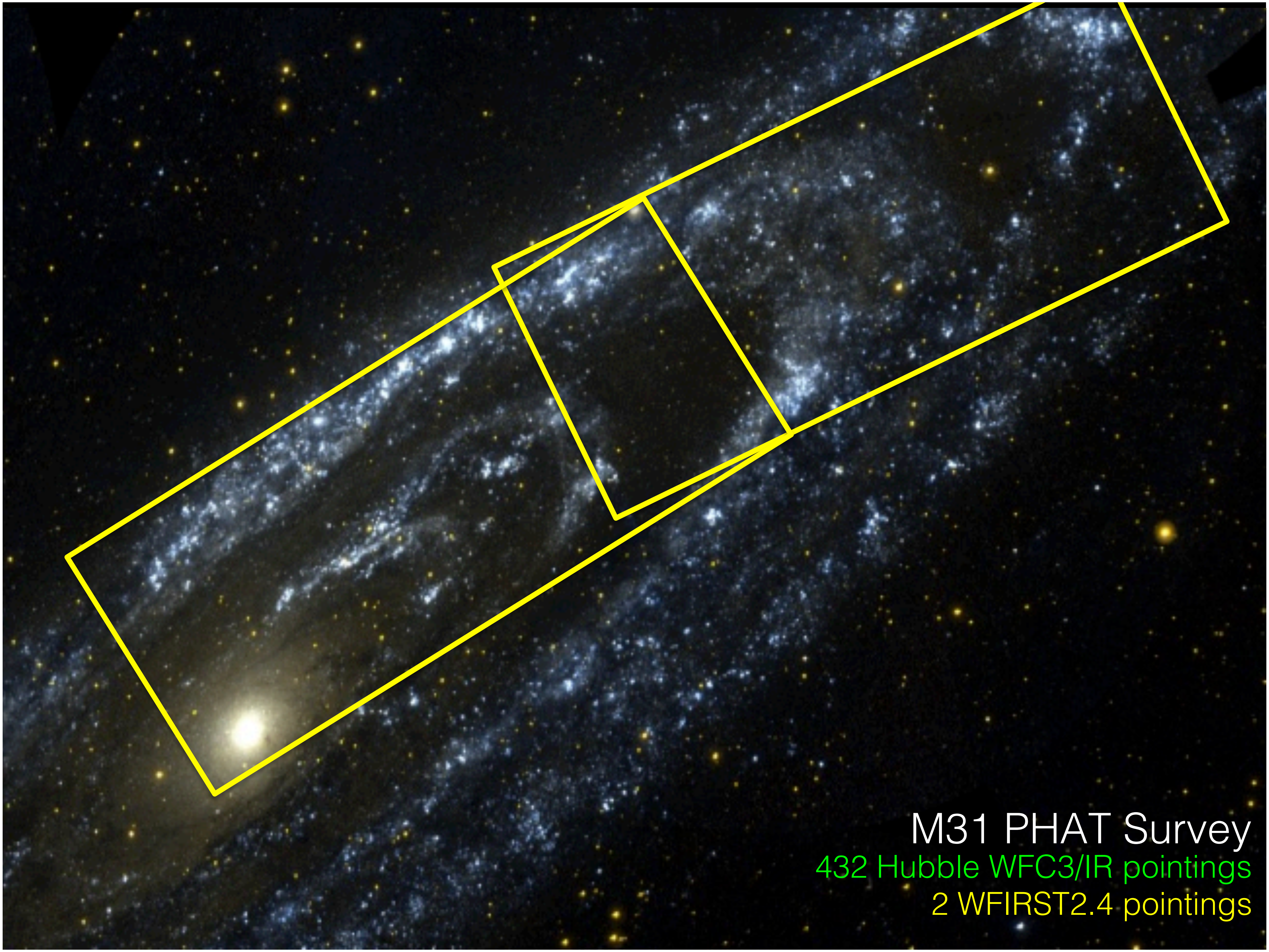
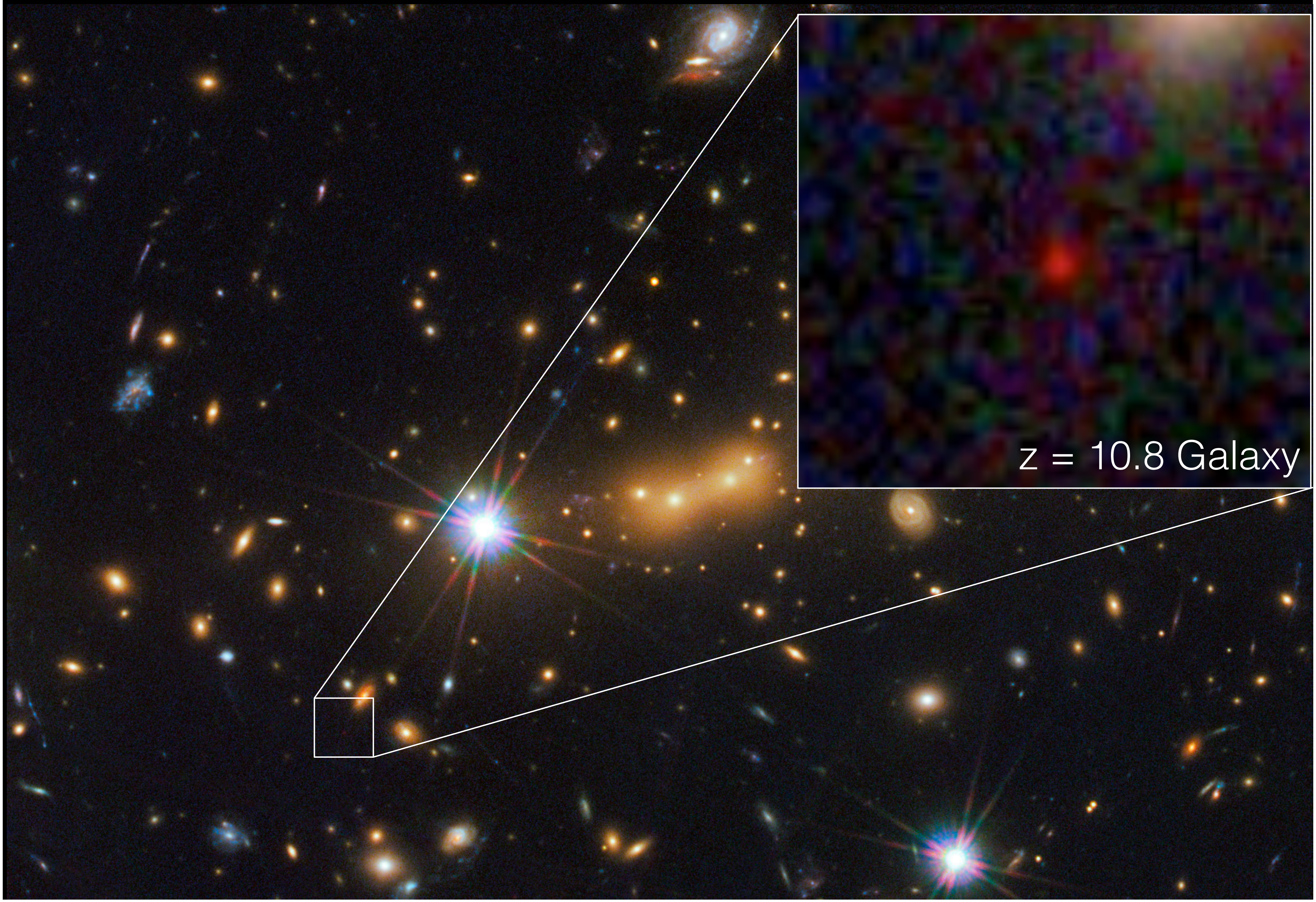
F110W
F110W − F160W
12 14 16 18 20 22 24 26
0 0.2 0.4 0.6 0.8 1
Sensitive IMF measurements
from M dwarfs
Missing Satellites Out to
Edge of Milky Way Halo
L [L⊙]
Combined Correction
Fixed Coverage Correction
Uncorrected/Observed
N(<M_V)
M_V
−2 −4 −6 −8 −10 −12 −14 −16


M31 PHAT Survey
Dalcanton et al. 2012


M31 PHAT Survey
432 Hubble WFC3/IR pointings

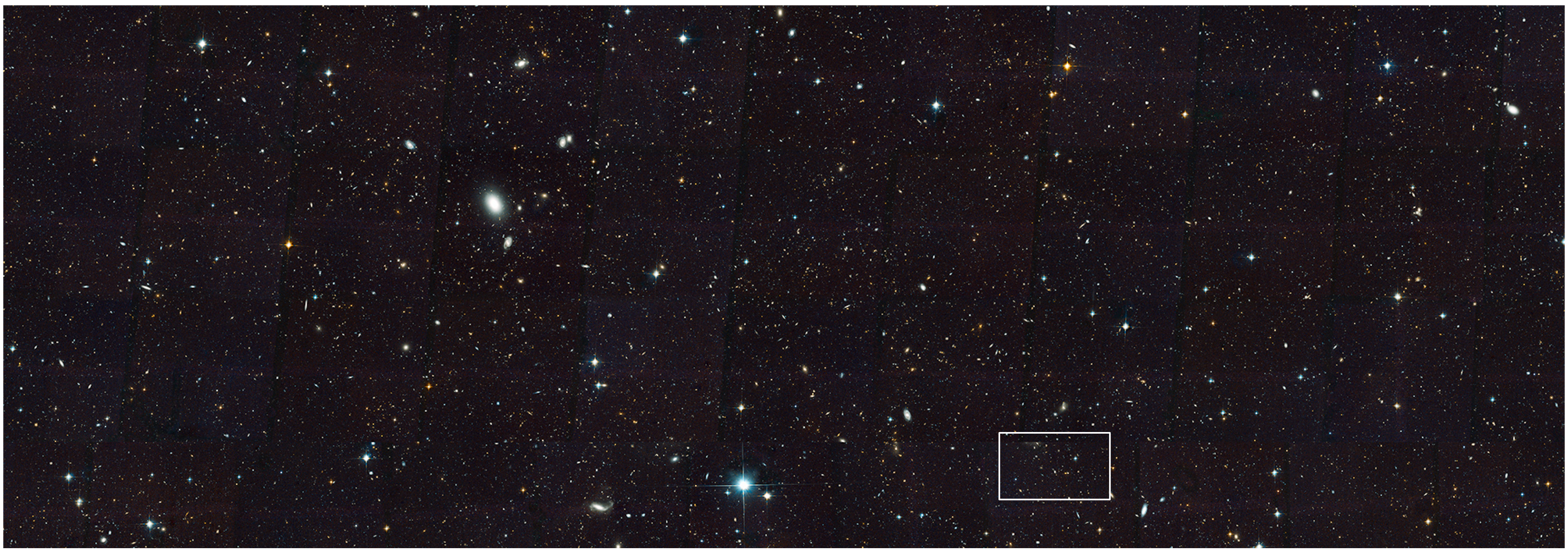

M31 PHAT Survey
432 Hubble WFC3/IR pointings
2 WFIRST2.4 pointings

Hubble X 200 = The Luminosity Function of High-z Galaxies



AFTA vs Hubble

Hubble Ultra Deep Field - IR
~5,000 galaxies in one image



WFIRST2.4 Deep Field
>1,000,000 galaxies in each image

AFTA vs Hubble GO Program

Hubble
Hubble/WFC3-IR is 25% of all observations
Hubble/WFC3-IR data led to 2 publications per week in 2013

AFTA
AFTA is 200x faster than Hubble WFC3/IR
AFTA has higher resolution than Hubble WFC3/IR
AFTA has higher efficiency than Hubble (i.e., on-source time)
→ Assume a conservative factor of 5 gain in science productivity

Assuming a conservative factor of 5 gain in science productivity
→ AFTA could yield **~500 scientific papers per year** from its GO mode